Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

MENDELIAN PHENOMENA WITHOUT DE VRIESIAN THEORY[1]

DR. W. J. SPILLMAN

U. S. DEPT. OF AGRICULTURE

THAT the phenomena of Mendelian segregation of character pairs is inextricably linked with the de Vriesian notion of pangenes is an opinion widely held, both by the advocates of the theory of discontinuous variation and by the opponents of that theory. Professor S. J. Holmes was one of the first American biologists to point out the fallacy of this idea.[2] He called attention to the fact that due consideration of the phenomena reported by Mendelian investigators did not lead to the theory of discontinuous variation as a necessary consequence.

While in the present paper it is my purpose to present an explanation of Mendelian phenomena without resorting to the idea of unit characters, I do not wish to be understood as belittling the important work done by de Vries and his followers. While contending that the de Vriesian doctrine that organisms are aggregates of separately heritable characters is unsound, I believe this investigator has uncovered a new type of variation which must be reckoned with as *a* means of evolution, not by any means the sole, or even the most important, means. For want of space, I am compelled, in what follows, to present some opinions without submitting all the evidence in favor of them. However, an attempt will be made later to present this evidence more fully. It seems to the writer that what Darwin considered to be fluctuating variations, amenable to the action of natural selection, may now be regarded as consisting of four distinct types of variation. First, we have those variations in the progeny of a given individual, or pair of individuals, which are due to what we may call "Mendelian recombination of characters."

---

[1] This paper was presented before the American Society of Naturalists, in Boston, Mass., December 29, 1909.

[2] See AMER. NAT., May, 1909.

Natural selection may have a very important influence on variations of this kind, since the variations are hereditary. The recognition of variations of this type must of course be attributed to Mendel, but de Vries, Correns, Von Tschermak and perhaps some others must be recognized as rediscoverers of this principle.

In the second place, after we have eliminated all variation caused by Mendelian recombination we still have a type of variation which is more and more coming to be called fluctuation, and which is due wholly to environment. Such variations are now believed not to be hereditary and therefore not amenable to the action of natural selection. In this connection we need only mention the important investigations of Johanssen on beans and barley,[3] the work of Nilssen and his able staff at Svalöf on wheat, oats and other species, and the recent classic work of Jennings on *Paramecium*.[4] The work of these investigators indicates strongly that selection is without effect on fluctuations due to environment. Dr. E. M. East, in Illinois Experiment Station Bulletin No. 127, reaches the conclusion that no effect of selection has been proven in clonal varieties of potatoes.

In the third place, de Vries found a type of variation which the cytological work of Gates,[5] Rosenberg[6] and Gager,[7] indicates to be due to irregularity in the distribution of chromosomes in mitosis.

Gates has shown that in the species with which de Vries worked there are irregularities in chromosome distribution. Furthermore, de Vries has shown that his mutants differ from each other in almost every detail, just as we should expect them to do if each of the chromosomes is more or less responsible for the whole process of development.

---

[3] W. Johannsen, "Ueber Erblichkeit in Populationen u. Reinen Linien," Jena, Fisher, 1903; Rep. 3d Int. Con. on Genetics, pp. 98–113.

[4] H. S. Jennings, *Proc. Amer. Phil. Soc.*, XLVII, No. 190, 1908; *Jour. Exp. Zool.*, Vol. 594, June, 1908.

[5] R. R. Gates, *Science*, January 31, 1908; *Science*, February 12, 1909, and elsewhere.

[6] O. Rosenberg, Rep. 3d Int. Con. on Genetics, pp. 289–291.

[7] E. Stewart Gager, Publications of New York Botanical Garden.

Rosenberg has shown that the irregularity of certain first-generation *Hieracium* hybrids is accompanied by irregularity in the number of chromosomes present.

Quite recently Gager, in his study of the effect of radium emanations on plants, has not only produced mutants apparently of the character of those found by de Vries, but has shown that in mitosis in treated specimens there is irregularity in the distribution of chromosomes. The writer some time ago suggested a similar explanation for the interesting work of McDougall in which mutants were produced by chemical stimulants. The behavior of the Rubus hybrid produced by Burbank, and resulting in the *Primus* berry, is so closely parallel to that of *Hieracium* hybrids studied by Rosenberg that a similar explanation at once suggests itself.

Boveri's classic work on the relation of chromosomes to development strongly supports the view that the de Vriesian mutants are due to loss or exchange of chromosomes, and this view is consistent with the work of Wilson, Morgan, Stevens and others on the relation of the chromosomes to sex.

I think, therefore, that we are in position to recognize, at least tentatively, a new type of variation, which is due to irregularities in the distribution of chromosomes, and which I shall call "de Vriesian mutation." These variations, being hereditary, are amenable to the action of natural selection, and must therefore be recognized as one method of evolution. In a certain sense these mutations are discontinuous, and the reason for this is apparently clear.

When we consider all the facts in the case, which I have not time here to outline, I think that few biologists will contend that all evolutionary changes are due to Mendelian recombination, or to de Vriesian mutation as defined above. The enormous diversity in groups having the same number of chromosomes, as well as observable differences in the chromosomes themselves, render any such view untenable. I therefore postulate a fourth kind of variation due to fundamental changes in what we may call the germ plasm, and I am inclined to believe that this is by far the most important type of evolutionary change. Whether changes of this character are continuous or discontinuous is not a very important question. It is more important to ascertain their cause and nature. I imagine they are largely chemical changes in the composition of, or changes in the relative amounts of substances present in, the germ plasm. If these changes are continuous the work of Johannsen, Nilssen, Jennings and East, above referred to, indicates that they are very slow. Such changes are certainly hereditary, and are thus a factor, and I believe the most important factor, in evolution.

One point regarding fundamental changes in the germ plasm it is important to remember: a gradual change might go on for a long time in the chemical activity of the cell before reaching a point where any outward manifestation of this change would appear. For instance; in some purple flowers there is reason to believe that the color is due to some such action as that of acids and alkalies upon the color of litmus, the flower being red or purple according to the amount of some substance present. Now a gradual change might go on in the relations between the substances concerned without producing any visible effect until a certain point is reached, when a marked effect is produced, giving what appears to be a discontinuous change, but what may be in reality a critical point in a slow and gradual change.

Riddle, in his recent very interesting paper on melanin color formation[8] has shown that in all probability melanin colors develop as the result of the action of an enzyme upon a chromogen, and that this action is a complex one. The chromogen is first converted into a new substance, the same enzyme then converts this substance into a third, and so on, producing a long series of substances. The early numbers in this series give no color, but finally a stage is reached where a number of steps in the series give color. Riddle seems to think that all the melanin colors found in organisms should be referred simply to the different stages of a single process of oxidation. This, however, can hardly be true. The fact that we get two or three kinds of pigment deposited in the same region of the organism, apparently at the same time, would indicate that there is more than one oxidation process involved. Furthermore, Riddle himself points out that, while in some oxidation processes series of colors occur extending from light yellow to black, with reds and browns as intermediates, in others the final stages of the oxidation processes are red. Quite a number of different oxidation processes are cited. Now the facts of color inheritance indicate that there may be several oxidation processes, and that in some of them a given color, for instance, red, appears as soon as color appears at all.

---

[8] *Biological Bulletin*, May 1909, pp. 316–351.

Assuming that the production of enzyme and chromogen is a general function of protoplasm, and assuming further that the relative amount of enzyme and chromogen present have a determining influence on the stage which the oxidizing process reaches in the organism, the phenomena of Mendelian color inheritance are easily explained without recourse to the idea of unit characters at all, as I shall now attempt to show. It must be understood that the figures in the following tables are merely illustrative and are not meant at all to indicate actual amounts.

TABLE I

Red and White Peas

Organs.	Relative Contributions.		F_1	F_2		
	Pure Red.	Pure White.		BB	BB'	$B'B'$
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Cy	25	25	25	25	25	25
AA	15	15	15	15	15	15
BB	30	10	20	30	20	10
CC	8	8	8	8	8	8
DD etc.	22	22	22	22	22	22
	100	80	90	100	90	80
	Red	White	Red	Red		White

Let us consider first the cross between red and white sweet peas, in which generation F_1 of the hybrid is red and generation F_2 gives us the ordinary Mendelian ratio of three red to one white. Table I shows an explanation of the Mendelian results on the assumption that every organ in the cell is concerned in color development. It is assumed in this instance, merely for purpose of illustration, that when the amount of enzyme present in the cell is 85 per cent. or more of the amount found in pure red races the oxidation process reaches the stage necessary to produce red coloration. The same end results would occur if, because of some peculiarity of a *single pair* of chromosomes in the white race, as compared with the red, the end result of the oxidation process in the white race gives no color.

In the first column of this table *Cy* represents the cytoplasm, and, in fact, all of the organs in the cell except the paired chromosomes. *AA, BB,* etc., represent pairs of homologous chromosomes. The second column gives assumed relations between the amount, say, of the enzyme produced by the different organs of the cell in the pure red race. It is assumed, for instance, that all the organs of the cell except the chromosomes produce 25 per cent. of this enzyme. The first pair of chromosomes produce 15 per cent., the second pair 30 per cent., and so on.

Now, with the assumptions made, a white race would result if a single pair of chromosomes produce markedly less of the enzyme than they produce in the red race. Column 3 shows the hypothetical conditions in such a white race. In the table it is assumed that in the red race the second pair of chromosomes produce 30 per cent. of the total amount of enzyme present, while in the white race, for some reason, this pair of chromosomes produces only one third of the enzyme it does in the red. Thus, in the white race we have only 80 per cent. of the amount of enzyme present in the red, and not enough to carry the oxidation process to the point of giving red coloration. The hybrid between these two races will have one chromosome producing its 15 parts and another chromosome producing only 5 parts, thus giving 20 parts where in the red race we had 30. In all, there is in the hybrid 90 per cent. as much of the enzyme as in the pure red. With the assumptions made the hybrid would therefore be red.

It is well known that heterozygotes frequently present vegetative vigor much greater than that of the related homozygotes. This may be possibly due to the greater opportunity certain chromosomes have of making more growth before filling the cell with their products. If such is the case, then the enzyme produced in our hybrid might exceed the mean between that produced in the two races crossed. This would explain the preponderance of cases in which the heterozygote resembles that parent which represents the more advanced ontogenetic stage. But there are not a few cases in which the heterozygote resembles the other parent. This happens to be the case in two of the first cases of dominance made out by the writer; namely, beards in wheat and horns in cattle. Both of these characters are recessive; or, as the de Vriesians would say, in them, absence is dominant to presence. Under the present hypothesis, we do away entirely with the presence and absence hypothesis, as will be seen later.[9]

In generation F_2 (Table I) one fourth of the progeny would possess a pair of chromosomes each of which produces its 15 parts of enzyme. One half of the individuals would have one chromosome producing 15 parts and another producing 5, while the remaining fourth of the individuals would have a pair of chromosomes each of which produces only 5 parts. We thus have one fourth of the population producing the normal amount of enzyme, half of it producing 90 per cent. of this, and one fourth of it producing only 80 per cent. This would give us three red individuals to one white.

It must be remembered that I am merely attempting to show here that it is possible to make assumptions that will explain Mendelian phenomena without resort to the idea of unit characters.

In Table II we have a more complex case; namely, that of the cross between red and white *Antirrhinums* reported by de Vries. In this cross de Vries found what is ordinarily called two pairs of Mendelian characters. Under the assumptions I have made this simply means that in the white race there are two pairs of chromosomes which were deficient in the amount of enzyme produced as compared with the pure red race used by de Vries in this cross.

---

[9] See article by Shull in AMERICAN NATURALIST, July, 1909.

TABLE II

Red and White Antirrhinums

Organs.	Relative Contributions.		F_1	F_2								
	Pure Red.	Pure White.		*AACC*	*AACC'*	*AAC'C'*	*AA'CC*	*AA'CC'*	*AA'C'C'*	*A'A'CC*	*A'A'CC'*	*A'A'C'C'*
	%	%	%	%	%	%	%	%	%	%	%	%
Cy	24	24	24	24	24	24	24	24	24	24	24	24
AA	30	*14*	22	30	30	30	22	22	22	14	14	14
BB	12	12	12	12	12	12	12	12	12	12	12	12
CC	26	*22*	24	26	24	22	26	24	22	26	24	22
DD etc.	8	8	8	8	8	8	8	8	8	8	8	8
	100	80	90	100	98	96	92	90	88	84	82	80
	Red	White	R	Red						Del.		Wh.

In the third column of Table II we have 14 parts of enzyme instead of 30 in the second column (chromosomes *AA*), and 22 parts instead of 26 in the second column (chromosomes *CC*). Since the hybrid gets one of each pair of chromosome from each of the parents it has 22 parts instead of 30, and 24 instead of 26. If, in this case, the amount of enzyme present in the cell is 85 per cent., or more of that present in the original red race with which de Vries worked, it is assumed that the oxidation process will reach the red stages. The hybrid in this case is red, though perhaps not so deep a shade of red as the pure red race.

In generation F_2 of this hybrid we have nine types. The first type is like the pure red race with which de Vries started. The third of these types is another pure race, but with a lessened amount of enzyme, and presumably less intense red color. The seventh type is also a pure race, but it is one which had only a little red at the margins of the petals and a type to which de Vries gave the name Delilah. The ninth type is also a pure race, which has white flowers and is like the pure white parent used in the cross.

De Vries states that in the reds and the Delilahs found in F_2 there was a good deal of variation, which is what we might expect from the relations shown in Table II, but he was able to group them, as shown at the bottom of Table II, and get the usual Mendelian ratios.

I have assumed here that when the enzyme is present in proportions from 82 per cent. to 84 per cent. of that in the pure red race, we get the Delilah type. This merely means that in the Delilah types the amount of enzyme present is near the critical point for the production of red color. There seems to be no question that the environment in the organism itself is a very important determining factor in the development of any character. It is not therefore fanciful to assume that in view of the fact that we get color development only in the petals the tendency to color development might be greater in one part of the petal than in another. We thus see that our assumptions are in agreement with the facts of inheritance made out by de Vries.

CRYPTOMERIC CHARACTERS

In one of Bateson's *Matthiola* crosses,[10] between a cream-colored and a white race, he found that the first cross was purple and that amongst its progeny it produced purples, reds, creams and whites. He explained these phenomena by assuming that red is due to two cryptomeric factors which are ineffective unless present in the same cell, while purple was due to a third factor which converted red into purple and which was found in the white variety. These phenomena may be brought in line with our hypothesis, as shown in Table III.

In this case we evidently have to deal with more than two chemical substances. For the production of the red character itself two of these substances are necessary. It is, of course, possible that in the simpler case considered earlier the same two substances, possibly others also, are responsible for red, but, there being a deficiency in only one of them, we get the phenomena considered in Table I.

---

[10] See Rep. III, Evolu. Com., Roy. Soc., 1906.

TABLE III

CRYPTOMERIC CHARACTERS

Bateson's Matthiola Crosses

R_1 = first factor for red; R_2 = second factor for red.

P = factor for purple. R_1 and R_2 produce red when present in greater proportion than 90 per cent. of normal amount in pure purples.

P converts red to purple when P is present in 90 per cent. of normal amount in pure purples.

Organs.	Cream var.			White var.			F_1		
	R_1	R_2	P	R_1	R_2	P	R_1	R_2	P
	%	%	%	%	%	%	%	%	%
Cy	18	20	24	18	20	24	18	20	24
AA	*12*	26	26	28	26	26	*20*	26	26
BB	14	16	12	14	16	12	14	16	12
CC	22	20	22	22	*2*	22	22	*11*	22
DD	18	18	*0*	18	18	16	18	18	*8*
	84	100	84	100	82	100	92	91	92

In the cross now under consideration we must assume that, taking the cream and the white races collectively, there are deficiencies in two substances necessary for the production of the red, as well as in the substance necessary for the production of the purple, or in one of the substances if more than one is necessary.

Let R_1 represent the first factor for red, R_2 the second factor for Red, and P the factor for purple. It is assumed that when either R_1 or R_2 is deficient to the amount of 10 per cent. of the amount of these substances found in pure purple races, the reactions will not reach the stage necessary for the production of red color, and that when there is a like deficiency in the substance necessary for transforming red into purple this transformation does not occur.

Column 2 of Table III shows the contribution of each of the cell organs to the substance R_1 in the cream variety; the next column gives similar data for substance R_2, and the next for the purple factor. The facts indicate that there is a deficiency in one pair of chromosomes (*AA*) for the substance R_1 in the cream variety; also for the purple factor in another pair of chromosomes (*DD*). These deficiencies are italicized in the table. In the white variety there is assumed to be a deficiency for the substance R_2 in a third pair of chromosomes. These assumptions give the phenomena found by Bateson. A similar case is found in sweet peas.[11]

It is seen in Table III that the cream variety has less of R_1 than is necessary to produce red coloration. It also has less of the purple factor than is necessary for converting red into purple, while the white variety has less of the substance R_2 than is necessary for the production of red.

Generation F_1 will have enough of all these substances to produce red and to convert red into purple.

The second generation of this hybrid contains 27 types. I will not here go into detail concerning that generation, but will merely add that the assumptions made are consistent with the facts observed in the second generation.

TABLE IV

HETEROZYGOTE CHARACTERS

Spotted F_1 beans from non-spotted P_1's.

S_1 = first factor of spotting; S_2 = sec. factor of spotting. S_1 and S_2 assumed to become operative when present in greater proportion than 85 per cent. of normal in pure spotted beans.

Organs.	♂ Parent.		♀ Parent.		F_1	
	S_1	S_2	S_1	S_2	S_1	S_2
	%	%	%	%	%	%
Cy	40	30	40	30	40	30
AA	36	*22*	*16*	42	*26*	*32*
BB etc.	24	28	24	28	24	28
	100	80	80	100	90	90

Table III deals with cryptomeric characters which are seen to owe their development to the reaction between two, or possibly more, chemical substances, the production of each of which is a generalized function of the cell. It is, of course, possible that each of these substances is produced only by a single chromosome, which case would be merely a limiting case in which all the cell organs except one produce none of a given substance in question.

---

[11] Rep. III, Evolu. Com., Roy. Soc.

Table IV deals with that class of characters which appear in heterozygotes, but not in pure races. Loche, Von Tschermak, Shull and Emerson have all studied such a character in beans. In certain crosses between beans not having spotted seeds the heterozygotes were spotted. Let us assume that the development of spotting on the seed coat is due to certain metabolic activities that involve at least two substances the production of which is either a generalized function of all cell organs or is a function of at least one pair of chromosomes. Let S_1 represent one of the substances necessary to these reactions, and S_2 another. Further, let us assume that in order to bring about the conditions necessary for the reaction both S_1 and S_2 must be present in a proportion 85 per cent. as great as in pure races of beans with spotted seed coats. In one of the races we assume a deficiency of substance S_2, and we assume that this deficiency is found in one pair of chromosomes only. In the other race there is a deficiency in substance S_1, and the same pair of chromosomes is responsible for this deficiency. Column 3 of Table IV shows 80 per cent. of the amount of S_2 found in ordinary spotted races of beans, while column 4 shows a similar deficiency in the substance S_1 in the other race.

Now generation F_1 of this cross receives one of the chromosomes in question from each of the parents, and in the case of each substance there is a deficiency of only 10 per cent. This gives us a spotted seed coat.

In the second generation, which is not shown in the table, one fourth of the progeny would be like the male parent and the other fourth like the female parent, neither of which has spotted seed coats, while half of the progeny would be like F_1 with respect to spotting of the seed coat.

While in this discussion it has been assumed that each of the substances with which we dealt was produced as the result of a general function of protoplasm, this is not necessarily the case. When we consider the history of the chromosomes it would appear very reasonable to suppose that marked variation in the composition, and consequently in the functions, of the chromosomes may have occurred as a result of evolutionary changes. It may be that some of the substances with which we have dealt are produced only by particular chromosomes, but we can hardly decide this question with the evidence at hand. In any case, particular chromosomes must be responsible for the deficiencies of the substances in order to get Mendelian phenomena. As previously stated, my object is simply to show that it is possible to make assumptions that will give us Mendelian phenomena without unit characters. The assumptions made seem to be consistent with the facts of physiological chemistry.

Even if we assume that the various substances with which we have been dealing are each produced by a single pair of chromosomes rather than by all the organs of the cell we can not look upon the chromosomes as the hereditary units spoken of by the de Vriesians and Weismannians, for we here look upon each chromosome as playing possibly an important part in the development of every feature of the organism.

The fact that in some species the number of pairs of Mendelian characters found is greater than the number of chromosomes is not an argument against the validity of the assumptions I have made. In Table IV we have assumed that the same pair of chromosomes may be responsible in one race for the deficiency of a certain substance and in another race for the deficiency of another substance. It happens in this case that the two substances concerned are both necessary to a particular reaction. If each chromosome play its part in the development of all parts of the organism, we might, in different races of a species, have a good many Mendelian characters dependent upon the same set of chromosomes, and instances of this kind are not wanting. For instance, Bateson found a particular flower color and a particular shape of the standard in sweet peas to be alternative to each other in inheritance. In other words, in the terms of our theory we have here two pairs of Mendelian characters based on the same pair of chromosomes. Several other similar cases are known. So that in order to prove that anything smaller than a chromosome is responsible for a Mendelian character difference it must be shown that we can get into a single individual more independent Mendelian character pairs than it has pairs of chromosomes. Both Baur and Shull, in private correspondence with the writer, have admitted the justice of this contention, and have promised to put it to the test.

Under the present hypothesis what has heretofore been called a pair of Mendelian unit characters must have a new name. For instance, in the red and white pea cross, if our assumption regarding the cause of the Mendelian phenomena is correct, we are not dealing with a pair of characters at all in the de Vriesian sense. Red is assumed to be a generalized function of the cell, and white likewise, but the difference between the red and the white concerns a single cell organ, and it is this difference with which we are dealing. Dr. McDougal, in conversation with the writer on this point a few days ago, suggested that in discussing this hypothesis we use the term "character differential" instead of character pair, and the suggestion seems to be a good one. We do, however, need a few terms, which I shall now proceed to introduce Under our hypothesis each of the organs of the cell is supposed to have various functions in development. One function may relate to the development of a particular character, and another to a very different character. Furthermore, several or all the organs in the cell may each have a function relating to the same character.

But not only are the organs of the cell supposed to play their part in development, but various organs, tissues and substances produced in the organism during development may also have functions which play a part in the development of various portions of the organism. For instance, hairs normally develop only in the skin. Hence the skin itself influences the development of hair. It is supposed that certain substances, called hormones, may materially affect the development of parts of the organism widely separated from the part of the organism in which these substances are produced. Thus the greater development of horns in the males of certain species is supposed to be due to hormones produced in the testes.

Any organ, tissue, substance or cell organ which thus has the power of influencing the course of development, I propose to call a "teleone." This word is from the Greek *teleo,* which means *make,* or *accomplish.* Teleones occurring in the egg, and presumably derived directly from the previous generation, may be called primary teleones. Those that arise during the course of development may be called secondary teleones. The manner in which primary teleones function in heredity has already been indicated. In a simple Mendelian character difference we are thus dealing, not with two unit characters, nor with the presence and absence of a single unit character, but with a difference between two teleones.

Under this hypothesis, transmission becomes, not the transmission of characters as such, but the transmission of cell organs having functions which determine character, or which influence development. This hypothesis may properly be called the teleone hypothesis.

A word about species crosses. We may imagine that, in species not closely related, the corresponding teleonic functions all differ more or less; hence we should not expect many simple Mendelian phenomena in such crosses. Again, in wide crosses, it will probably happen frequently that the chromosomes brought together will be so dissimilar that they do not act together in the usual manner, especially in the reduction division. We should expect Mendelian phenomena only in cases where homologous chromosomes go through synapsis and reduction in a formal manner.

Finally, when character differentials relate to anything other than chromosomes, Mendelian splitting should not occur. I would therefore suggest that some of the character differentials studied by Castle in rabbits are due to cytoplasmic differences, or at least are not due to the chromosomes.